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# Lean Manufacturing evaluation focused on Green Practices Adoption in Amazonia

## Resumo

*O objetivo deste trabalho é realizar uma avaliação lean manufacturing com foco na adoção de práticas verdes em uma empresa química do Polo Industrial de Manaus. Em termos de abordagem do seu problema, este estudo caracteriza-se como uma pesquisa qualitativa, com relação aos objetivos, caracteriza-se como uma pesquisa exploratória e quanto ao procedimento metodológico, caracteriza-se como estudo de caso. As técnicas de pesquisa utilizadas foram: (1) documentação indireta (pesquisa documental e bibliográfica), (2) a observação direta intensiva (observação estruturada in loco e entrevista semiaberta); e (3) observação direta extensiva (aplicação de formulário). Entre os principais resultados evidenciam-se (1) a redução do lead time nos processos; (2) a possibilidade de redução dos custos; (3) e o aumento da qualidade. A relevância da pesquisa reside na aplicação de uma abordagem que possibilite analisar a sinergia entre lean manufacturing e as questões ambientais na busca pela redução de desperdícios, eficiência operacional e aumento de competitividade.*

**Palavras-chaves:** Lean Manufacturing; Indústria Química; Práticas Verdes; Amazônia.

## Abstract

*The objective of this work is to carry out a lean manufacturing evaluation focused on the adoption of green practices in a chemical company of the Industrial Pole of Manaus. In terms of approach to its problem, this study is characterized as a qualitative research, in relation to the objectives, is characterized as an exploratory research and as to the methodological procedure, it is characterized as a case study. The research techniques used were: (1) indirect documentation (documental and bibliographic research), (2) intensive direct observation (structured observation in loco and semi-open interview); and (3) extensive direct observation (application of form). Among the main results are (1) the reduction of lead time in the processes; (2) the possibility of reducing costs; (3) and increasing quality. The relevance of the research lies in the application of an approach that makes it possible to analyze the synergy between lean manufacturing and environmental issues in the search for waster eduction, operational efficiency and increased competitiveness.*

***Key words**: Lean Manufacturing; Chemical industry; Green Practices; Amazonia.*

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## 1. Introduction

The great changes in the world scenario in the industrial sector originated from the automobile companies. The new production management models developed and applied in the Japanese market emerged from a set of innovations that Toyota, an automotive company, had been applying and testing since the middle of the last century (WOMACK *et al*., 2004).

The origins of the Toyota Production System (TPS) are related to Japanese cultural, geographic and economic aspects. The limitations of resources and spaces, as well as Eastern culture oriented more to systems than Western culture, as well as the more concentrated location of industries are pointed as factors of Japanese success (HOPP & SPEARMAN, 2013).

Just-in-Time (JIT) differs from traditional philosophy (Just-in-Case), as it seeks to respond dynamically and instantaneously to the varied market demand, usually producing small batches and inventories (both raw material and finished products) be viewed as wastes. Finally, JIT implies linearization and simplification of the production system. On the contrary, the Just-in-Case philosophy prioritizes the use of the production structure, divided into fixed sections, which is optimized by the production of products in large lots and is subject to the batch formation (ANTUNES JÚNIOR *et al*., 1989).

From the 1990s, the term JIT was gradually replaced by lean manufacturing. Thus, in a retrospective view, the lean production provided a better set than several JIT techniques, the focus was on flow, the chain of values and the elimination of Muda (waste), through Kaizen events (HOPP & SPEARMAN, 2013).

Lean strategies describe the application of quantitative methods and human resources to the improvement of materials and services provided in an organization. Lean manufacturing (LM) integrates key management techniques, improvement efforts, and technical tools used in a disciplined approach based on the principles of continuous improvement. Since the 1990s, lean strategies along with green engineering practices have been applied at work sites to reduce waste, streamline processes, improve efficiency and as a result increase productivity (KUMAR & THOMAS, 2002).

The evolution of manufacturing strategies went through traditional manufacturing (substitution-based), followed by lean manufacturing (waste reduction-based), then it is green manufacturing based on the 3Rs (reduce, reuse and recycle) and conclude in sustainable manufacturing (innovative) based on the 6Rs (reduce, reuse, recycle, recover, redesign and remanufacture) (JAWAHIR *et al*., 2006). Sustainable manufacturing can be understood as the manufacture of products that utilize less environmentally, socially and economically viable productive processes, but green manufacturing cannot be seen as a production system, such as lean manufacturing based on the Toyota Production System, but rather as a result of environmental management practices in manufacturing processes not presenting a model to be generalized (INTERNATIONAL TRADE ADMINISTRATION, 2010; BERGMILLER, 2006).

Therefore, the objective of this work is to perform a lean manufacturing evaluation focused on the adoption of green practices in a chemical company of the Industrial Pole of Manaus. The work is structured in three parts: (1) literature review; (2) methodology; (3) results, discussion, conclusion, and references.

## 2. Literature Review

### 2.1. Toyota Production System and Lean Manufacturing

The Japanese market at the beginning of the 20th century had very specific characteristics, such as limited domestic market (wide range of vehicles), demand for smaller vehicles, the absence of physical spaces, the government prohibited external investments in the automobile industry, among others (WOMACK *et al*., 2004).

The TPS is based on the complete elimination of wastes, with Just-in-Time (JIT) and autonomy (human touch automation) as its two supporting pillars. In addition, the Zero Defect Quality Control (ZDQC) can also be considered as an essential element for the operationalization of the autonomy and functionality of the system as a whole (GHINATO, 1995). The TPS also promotes 5S, *Seiri*, *Seiton*, *Seiri*, *Seiketsu*, and *Shitsuke*, being organizational techniques and housekeeping that aim to achieve autonomy and visual control (HOOP & SPEARMAN, 2004).

Therefore, the basic idea of the TPS is to maintain a continuous flow of the products that are being produced aiming to obtain flexibility to the changes of demand. The implementation of this flow is called production at the exact moment and means producing only the necessary items in the required quantity and in the time required (MONDEN, 1984).

The work of Ohno (1997) also points to other important concepts related to TPS, such as “five why” (help to find out the root of the problem and correct), change (wastes), andon visual control, teamwork, and Kanban. In addition, another important issue in the system is heijunka, that is, the process smoothing the flow of production, which together with the reduction of setups, functional training and factory layout (U-cells) are essential for a cycle time and a faster response in customer service (HOPP & SPEARMAN, 2013).

The work of Schonberger (1982) indicated four approaches that companies should adopt to become lean: (1) reallocating floor space, (2) cutting setup time/lot sizes; (3) drawing down buffer stocks; and (4) reducing number of suppliers. According to Liker (2005), the heart of the TPS is the elimination of wastes; in this case, the author identifies eight types of wastes: (1) overproduction; (2) waiting; (3) transport; (4) super processing; (5) excess inventory; (6) unnecessary movement; (7) defects; and (8) waste of employee creativity.

The work of Shigeo Shingo (SHINGO, 2000) presents the methodology for reducing machine set-up time called SMED (Single minute Exchange of die) being conceived over 19 years. The author identifies as internal setup the set of activities performed with the machine stopped and external setup as the set of activities with the machine in operation (SHINGO, 2000).

From this context of tools, approaches and methodologies developed over the years, lean manufacturing (LM) is a dynamic process of change driven by a systematic set of principles and best practices aimed at continuous improvement. The LM combines the best features of mass production and art production. Lean manufacturing can be defined as an alternative integrated production model because it combines distinct tools, methods, and strategies in product development, management and operations management into a coherent whole. It is a philosophy that when implemented reduces customer order time to delivery by eliminating sources of waste in the production flow, and is a system designed to compete based on the advantage of a product where continuity is unlikely, and then instead of avoiding competition, faces head-on (LIKER, 1996; WOMACK *et al*., 2004).

Lean Manufacturing is a philosophy based on the Toyota Production System and other Japanese management practices that strive to shorten the timeline between the sales order and the final product shipment by consistently eliminating waste. It means developing a value stream to eliminate all waste, including time, and ensuring a time schedule as well as an efficient way to satisfy the customer while offering the manufacturers extra competitive (NAYLOR *et al*., 1999; SHINGO, 1996; STORCH & LIM , 1999).

Among the main general concepts related to lean production stand out: (1) development of simple mold exchange techniques; (2) production in small lots; (3) company as a community; and (4) more flexible workers in the tasks and assets in promoting the interests of the company. These concepts provoked changes in the assembly line where workers started to group into teams, teams began to perform cleaning tasks performing small repairs of tools and quality control, reserved periodic schedules to suggest improvements in processes, in addition to the worker stop the assembly line. Further, it adopted demand-driven production, Kanban implementation, and combating waste (WOMACK *et al*., 2004).

Kanban represents the first system to use the term "pull". The kanban in its classic version had its origin in Toyota called "two-card kanban" system, which had as a function to initiate the production of the parts, besides providing the necessary quantity that was to be produced. Different from the pull production system, in the push system, the work starts from the subtraction of an established lead time from the date the material is needed, either for shipping or for assembly. Therefore, the pull production system has the following benefits: (1) reduction of WIP and cycle time; (2) smoother production flow; (3) improved quality; and (4) reduced cost (SPEARMAN & ZAZANIS, 1992; HOOP & SPEARMAN, 2004).

Within the general concepts, it is important to differentiate the cycle time from takt-time. The cycle time deals with the time in which a unit of a product must be produced as a result of the ratio between the actual time of daily operation and the required daily quantity of production (MONDEN, 1984). Takt-time is defined based on market demand and the time available for production, that is, the rate of production required to meet demand, resulting from the ratio between the time available for production and the number of units to be produced. Takt-time is the production rate required to meet a given level of demand, it is the time that governs the flow of materials in a row or cell (ALVAREZ & ANTUNES JÚNIOR, 2001).

Value Stream Mapping (VSM) is a tool that helps you visualize and understand the flow of materials and information of a particular product through the flow of value. The value stream is all the actions (value added or value added) required to deliver products through the main flow of each product, that is, through VSM it is possible to visualize not only the process flow but to observe the sources of waste, making possible the connection between the flow of information and material (ROTH & SHOOK, 1998).

More recently, Sá (2010) developed the WID (Waste Identification Diagram), a tool to support managers with the objective of identifying the various types of wastes in the production process. Among the objectives of the WID are: 1) to represent not only the flow of one family of products but of all products simultaneously; (2) identify and evaluate all types of wastes, visually; (3) providing effective visual information; (4) present information through performance indicators; (5) promote continuous process improvement (DINIS-CARVALHO *et al*., 2014).

## 2.2 Methods for evaluation of Lean Manufacturing

Karlsson & Ahlstrom (1996) develop a model used to evaluate the challenges for the introduction of lean production. From the book The Machine That Changed the World, the authors summarize the most important principles within lean production, such as waste elimination, continuous improvement, zero defects, Just-in-time, multifunctional teams, decentralized responsibilities, among others.

Sánchez & Pérez (2001) developed and tested integrated checklist to evaluate changes in manufacturing toward lean manufacturing. As a result of a survey in companies located in Spain, the authors analyzed that the indicators of lean manufacturing are more used to evaluate the improvements in their production systems. Goodson (2002) describes a lean evaluation technique called the Rapid Plant Assessment (RPA) process. According to the author, when using the RPA process during a tour by a company, it becomes possible to indicate if the company is truly lean in less than 30 minutes from two tools, the RPA rating sheet and the RPA questionnaire, between the measures customer satisfaction, production flow, inventory, visual management, levels of work in process, among others.

In a survey, Soriano-Meier & Forrester (2002) examined the relationship between the main components of the work of Karlsson and Ahlstrom (1996) and managerial commitment (BOYER, 1996) for the implementation of lean manufacturing. The authors point to a strong relationship between managerial commitment to Just-in-time and quality management and investments to support manufacturing infrastructure.

Nightingale & Mize (2002) present the Lean Enterprise Self-Assessment Tool (LESAT), a tool used in more than 20 companies during its testing phase, to guide companies to implement lean thinking by assessing their current status, based on your lean ability as well as a set of goals for future steps. Pavnaskar *et al.* (2003) use a classification scheme that serves as a link between problems with production wastes and lean manufacturing tools. The purpose is to correlate a productive loss with the most appropriate lean tool. Therefore, this scheme organizes the lean manufacturing tools and metrics according to the level of abstraction and appropriate location for application of the tool in the company.

Kojima & Kaplinski (2004) present the construction of a lean production index and the analysis of the determinants of its adoption in the auto components sector in South Africa. The indicator is composed of three indices related to flexibility and logistics; quality; and continuous improvement. In this paper, Cardoza & Carpinetti (2005) discuss the process of development and implementation of performance indicators in the lean production system. The authors point out the differences between the indicators of the lean production system in relation to the mass production system.

Doolen & Hacker (2005) developed an instrument to evaluate the implementation of lean practices within an organization from an exploratory study in electronic industries. The survey considered six impact areas related to lean manufacturing principles and practices pointed out in the literature. Walter & Tubino (2013) carried out a review of the literature on the scientific methods related to the subject between 1996 and 2012. The authors point out the case study as the methodological approach most used in the area.

Singh & Sharma (2010) developed a method for measuring leanness in the auto component industry. The method is based on the leanness measurement team (LMT) judgment and evaluation on various supplier parameters, investment priorities, lean practices, wastes, and customers. Wilson (2010) presents eight steps for the implementation of lean manufacturing, starting with cultural change, evaluating the current state and ending with the implementation of kaizen activities and evaluation of the implementation in the company.

## 2.3 Synergy Between Lean and Green Manufacturing

In recent years, environment and energy have emerged as key components of the design, production, and withdrawal of goods and services systems; in addition, modern industrial engineering, from a completely new perspective, seeks to create environmentally and socially acceptable renewable products in a factory without waste. This is the lean green industrial engineer. Both the green and lean manufacturing have strong conviction that people are responsible for the current and future impact of waste of natural resources and energy. At the factory, green manufacturing identifies the types of waste, emissions, raw materials and energy used for the production, distribution and support of the final product (BLACK & PHILLIPS, 2010).

Green manufacturing is generally used to define an environmentally friendly activity. The goal of green manufacturing is to design and produce products in an environmentally friendly manner, using techniques and processes to minimize environmental impact. The characteristics of a range of environmentally friendly products reflect the use of recycled and recyclable materials, the use of components or the design of products that can easily be disassembly, leading to low environmental impacts and generation of waste (GUPTA, 2016).

Lean initiatives are focused on maximizing productivity by increasing output per unit of input, conserving resources, reducing waste and minimizing costs, while green initiatives relate to environmental protection, including eco-product design, design for the environment (DfE), design for reuse, remanufacture and recyclability, reduction and elimination of toxic materials and the use of environmentally friendly raw material. These initiatives also include life-cycle assessments to understand all the environmental implications of products, processes and services (DHINGRA *et al*., 2014).

Lean not only serves as a catalyst but also synergistically for the green, this means that lean is beneficial to green practices and the implementation of these practices also has a positive influence on existing practices in the company, facilitating green implementation. The difference between the lean and green paradigm lies in focus, especially considering the aspects of waste, customers, product design, manufacturing strategy, life cycle management, KPIs, and costs. However, lean and green reduce environmental impact and increase productivity in resource use, reducing costs and increasing productive performance (DUES *et al*., 2013, PAMPANELLI *et al*., 2014).

In terms of research, Sobral *et al*. (2013) examined how adopting lean manufacturing practices can generate environmental benefits for a large automotive multinational, as well as investigating how production and environmental managers observe the relationship between lean and green on a daily basis in operations. Sant'anna *et al*. (2017) propose a method evaluating the level of implementation of lean and green approaches. The results indicate critical practices that should be prioritized by suppliers in search of a synergy between lean manufacturing and environmental management.

Mittal *et al*. (2016) propose a hybrid lean-green manufacturing system (LGMS) considering the existence of several issues that may hinder the implementation of such a system, as well as the holistic improvement of the performance of the manufacturing system. Diaz-Elsayed *et al*. (2013) Identify an approach for incorporating lean and green strategies into a manufacturing system. The authors performed an evaluation of these strategies by means of simulation of a manufacturing system, afterwards the optimization took place and, at the end, the application took place in an automotive company.

Graza-Reyes (2015) points out that the development of the lean and green area is still at an early stage with most articles published in the last five years. The main six streams of research in the area these being directed to explore:: (1) their compatibility, (2) their amalgamation, (3) their integration with other paradigms, (4) methods/indicators to measure their contribution and effect, and their dependencies, on the performance of organizations, (5) their impact on organizational performance, and (6) their application in various organizational functions and industries.

## 3 Methodology

### 3.1 Study Design

In terms of approaching their problem, this study is characterized as a qualitative research (SILVA & MENEZES, 2005; DEMO, 2009) due to the application of the form for evaluation of lean-manufacturing practices, interpretation of nonlinear interview data and structured observation. With regard to the objectives, it is characterized as an exploratory research (SILVA & MENEZES, 2005), as it aims to provide greater familiarity with the problem with a view to making it explicit, in this case, the chemical company of the Industrial Pole of Manaus.

As for the methodological procedure, it is characterized as a case study since it possesses characteristics of empirical work when investigating a certain phenomenon within a contemporary real context from an in-depth analysis of one or more objects of analysis - cases (MIGUEL, 2012 ), such as individuals, groups or organizations (BENBASAT *et al.*, 1987). The case study allows us to deal simply with complex situations considering that a phenomenon is influenced by the context in which it is inserted (BAXTER & JACK, 2008).

In the case of operations management and related areas, evidence demonstrates the contribution of cases in terms of the construction of theories in new areas and the integration between applied theory in new contexts (BARRATT *et al.*, 2011; MEREDITH, 1998), preparing for (MCCUTCHEON & MEREDITH, 1993) and with scientific rigor appropriate to the area (VOSS *et al.*, 2002).

Unlike the traditional rationalist studies that work with representational inferences or statistical generalities, the case study works from relational inferences or analytical generality, in the search to generalize the results of a study to create a theory, besides the attempt to determine if a factor is related to another (MEREDITH, 1998; YIN, 1994).

The case study allows (GIL, 2002):

1. Explore real-life situations whose boundaries are not clearly defined;
2. Preserve the unitary character of the object studied;
3. Describe the situation in the context in which a particular investigation is being carried out;
4. Formulate hypotheses or develop theories; and
5. Explain causal variables of a particular phenomenon in very complex situations that do not allow the use of surveys and experiments.

## 3.2 Research Framework

The approach used in the research was the application of software developed and presented by Kumar & Thomas (2002), called Lean 1.0. For this, the questions of the software were adapted in a form with field destined to identify the evidence to be applied in the company. The form was composed of 70 questions that evaluated lean manufacturing practices focused on the adoption of green practices divided into four criteria: (1) materials and inventory, (2) training, (3) quality and (4) preventive maintenance.

The criterion (1) materials and inventory have 17 questions; (2) training, 19 questions; (3) quality, 13 questions; and (4) preventive maintenance, 21 issues. Each of these criteria was classified according to the evidence found and presented by those responsible at different scales (yes/no, always/rarely/never, always/sometimes/never, often/sometimes/never, completely/partially/Never).

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## 3.3 Characterization of Company

This work was carried out by a chemical company, is one of the most well-known and respected manufacturers of hygiene and cleaning products in the world, the company began its activities in the waxing segment, expanding to other categories such as hygiene and cleaning, personal care, insecticides and more recently, domestic storage, always being highlighted by innovation.

The first Brazilian subsidiary came in 1960, located in Rio de Janeiro. In 2008, the factory of Manaus (AM) was inaugurated. Currently, the administrative headquarters remain in Rio de Janeiro and has the support point of the Commercial and Distribution Office, both in São Paulo, and laboratories in São Paulo and Santa Catarina. Today the Company has about 320 employees in Amazonas. Figure 1 shows the factory floor.

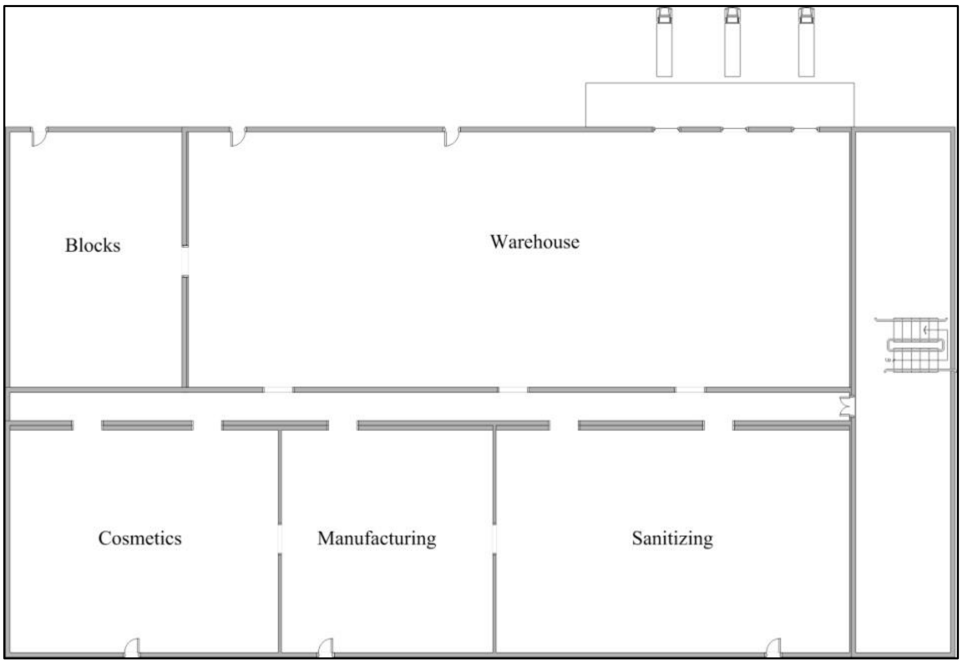



**Figure 1** – Factory floor – Manaus
**Source:** Authors

### 3.4 Methodos of Data Collection

The sampling of the research was intentional non-probabilistic (MARCONI & LAKATOS, 1990). The research techniques used were: (1) indirect documentation (documental and bibliographic research), (2) intensive direct observation (structured observation *in loco* and semi-open interview); and (3) extensive direct observation (application of form).

The research was carried out in five moments: (1) individual semi-open interviews were held (VERGARA, 2009) with company managers (lean manager, training leader, maintenance manager and quality engineer) from a script based in Guérin *et al.* (2001) to better understand the company considering several socio-economic aspects of the organization studied, later; (2) documentary research was conducted in order to collect data in written documents (internal company documents); (3) followed the structured observation (VERGARA, 2009) in the various sectors of the organization; (4) followed the application of the LM practices form with the managers (after observation and interviews); finally, (5) data analysis and tabulation were performed.

### 3.5 Methodos of Data Analysis

The qualitative data obtained from the interview responses were tabulated and grouped according to the content and stratified according to the structure of the LM practice form. The documentary information collected at the second moment was integrated and triangulated with the information collected by the interviews in order to ensure rationalization and validation. To analyze the qualitative data, a methodology proposed by Kvale (1996) was adopted adopting the following analysis steps:

1. It began with the description of the subject from the experience of the owner during the interview;
2. It was sought to discover new relationships of the theme and how the interviewee observes and puts it into practice;
3. During the interview, we sought to condense and interpret the meaning of what the owner describes, disseminate and return in feedback until there is only one possible interpretation or multiple understandings of the subject by the subject;
4. The transcribed interview was interpreted individually. The material was structured and the clarification followed in the search to eliminate repetitions and distinctions between the essential and the non-essential. The analysis involved the development of the meanings of the interview, bringing the subject's own understanding, as well as providing new perspectives of the researcher on the analyzed phenomenon.
5. The interview had a character of action by allowing the respondent, from the questions, the beginning of new insights about the LM practices that could be adopted by the company.

Finally, the data from the LM practice form was released in Lean 1.0 software and handled in a way that allowed an adequate visualization through the radar chart and enabled an adequate characterization of the company.

## 4 Results

### 4.1 Materials and Inventory

The material and inventory criterion work through improved and efficient management of all materials used or generated at each stage of the process. These materials are essential to rationalize processes and increase productivity. This criterion helps to identify potential wastes of previously unknown materials and waste streams.

With regard to ISO 9001 and 14001 certifications, the company does not require the certification of its suppliers. The question of environmental performance, health and safety and its specifications are in the FISPQ (Safety Data Sheet of Chemicals) and also in the standardized form of the company called Emergency Card. Suppliers are not required to evaluate environmental costs in both the company and the lower supply chain because this type of assessment is carried out by the company. Currently, the number of suppliers meets the needs of the company.

In relation to inventory management, vendors do not track data as this activity is performed by company employees in each industry. As for the reduction of costs of the suppliers, there is an opportunity to purchase specific material for the reduction of raw materials. The withdrawal of obsolete or obsolete products is not carried out by suppliers and is implemented by the SGOP (Operational Management System).

The inventory of materials is carried out in a cyclical and annual period. In the cyclical period it is carried out every three months by the deposit manager and all his staff, and within this cyclical period, the daily counting of the materials is carried out. In the annual inventory, the factory for three days in the month of November and all areas participate, but the count is performed by the line leaders and their operators. During this period, the company's areas of activity, such as quality, safety, engineering, administrative, fiscal, warehousing and others, participate and contribute to the closing of this count and the commitment of numbers.

The chemical management service is tracked from the input, processing and when they are sent to the production lines. There are controls, such as inspection and control forms, to verify whether or not the management of such products is being carried out, validated for the factory's three shifts of production. In the case of the layout of materials within the work area, the flow is not adequate in the work area and there is a need for adjustments and changes. The inventory system used is the FIFO tool (first in and first out) used within the inventory management system. This is one of the methods that covers all the reliability of the controls by a system or in loco.

In conclusion, wastes of materials caused by spillage or other manual material problem are accounted for and occur sporadically within the manufacturing processes.

## 4.2 Training

The training criterion deal with the education of employees in lean techniques and their importance. The workforce needs to be informed about the benefits of following green lean practices to ensure success.

With respect to the replacement of obsolete or polluting machinery and equipment, machinery is annually gaining new investments and obsolete machines are being replaced by more efficient and less polluting machines, as the company strictly complies with environmental policies, especially considering its location in the Amazon. All lines are automated and certified to act in accordance with required policies with their trained employees on each new machine upgrade.

As far as inspections are concerned, they are carried out by means of gembas carried out by the entire company leadership in order to maintain order and compliance with the standards. Containers or storage facilities are used sporadically since the finished products go directly to the distribution centers. The storage area is configured as the warehouse (finished products) of the company; this place meets the need of all areas. Besides this place there are other smaller ones to attend needs of the administrative activities, everything divided and organized.

Regarding overproduction, it rarely occurs, according to reports, however, when this happens the SAP system and hourly production monitoring show deviations. With regard to production delays, there is rarely a production lag event, considering that the schedule is planned in an alignment meeting a week earlier by the entire management. Every operation meets the requirements to not waste time on unnecessary movements in the day-to-day work.

The company works with the SAP system in order to detect production problems; in it happens all the management of the plant and for the production area, the errors are detected and corrected in order not to cause inconvenience or wastes for the company.

With reference to the recovery of products from customers and retailers, the quality sector has control of the Customer Service Department (SAC), where what is related to customers passes through this filter and a team seeks to solve any situation of the customer. All management participates in the development of employees, serving as facilitators for the production environment and other areas. The managers coordinate all the projects that involve training internally the TPM (Total Productive Maintenance) management tool, in addition, there is the pillar of T&D (Training and Development), and this pillar is focused on training activities for the entire plant.

In the factory, there is specific training for each activity to be performed. Therefore, every fiscal year a PAT (Annual Training Plan) is carried out and within it, several programs unfold including the diverse needs of the company and the qualification of the employees. Meetings are held on a daily basis, either in an office or in the production environment with the participation of production and management assistants resulting in minutes of meetings and shift shifts.

The T&D pillar works with the line mapping tool, providing stratification of all the equipment of the line and demonstrating in detail how to reduce the setup time. It also uses the methodology 70-20-10, where the idea of APT (Autonomous Production Time) is worked, in which they have an array of training skills developing activities to reduce setups.

As for the success of other areas of the company, everything is shared with the company. In the production environment, there is a management tool called "Idea of Improvements", where it involves improving any process or activity with a simple idea. When the idea is relevant and meets other needs in the other areas or even in another unit, replication occurs causing a significant impact on the management indicators.

## 4.3 Preventive Maintenance

The preventive maintenance criterion refers to the proper maintenance procedures for the processes and machines ensuring that they are in the correct place (layout). Breakdowns, damage to equipment, waste, leaks, among others, can be avoided by appropriate preventive measures.

Regarding the substitution of hazardous materials for unregulated, the company realizes investments in improvement focused in partnership with the sector of security in the machinery. The environmental sector promotes training with the fire brigade for spill prevention; the company has professionals to provide support beyond the employees who are trained by the organization. With regard to the monitoring of storage tanks, inspection by the security sector occurs daily. It happens to comply with the standards, determined by the company's policies and also by the bodies that conduct inspections and audits. There has been training since the integration, called LOTO, where basic security instruction occurs to work in all sectors of the company.

The security industry periodically performs events throughout the unit to demonstrate the security procedures that exist. It also implements the DSS (Sustainable Security Dialogue) weekly and mentions the procedures that each sector has how to use them and how to keep the updating of the forms up to date. In the production environment, there is a procedure called BOS (Safety Occurrence Bulletin) where the employees themselves take care of their own safety, that is, it is an active program that has already had relevant results in the organizational indicators.

In terms of the elimination of dirt and scrap, the company adopts Lean Manufacturing tools, especially the 5S program, where activities are carried out by all employees (leaders, operators, and auxiliaries). In addition, there are weekly audits to verify that procedures are being fulfilled and resulting in reporting. What is not in compliance is placed in the plan of action to be done later and aiming to be in compliance with the next audit.

Worksite clean times happen in every industry with their shared schedule on the company's internal agenda. This cleaning is done during normal working hours by everyone, as the company discards overtime work. In the production environment, this cleaning time happens at the end of production, usually before the shift.

The company adopts a visual management tool, called "Centerline", used to measure equipment; by means of it define the parameters of use of the equipment and are identified for any employee to identify and analyze the limits of the equipment.

With respect to the maintenance and repair manual of the various equipment, the maintenance and engineering areas work together to keep the maintenance manual up to date on the files and especially on the production lines. The technicians are trained to know the equipment in order to meet their needs. The great majority of the manuals arrive in the English version resulting in a planning for translation and print and virtual availability for the others. The equipment history is in updated files and easily accessible by any collaborator. Since the machinery was installed in the production environment there is a virtual and physical history, as well as monitoring the machine through on-site monitoring and the SAP management system.

Maintenance planning is as follows: the company has a blue and red label where the blue label is planned in the opening order, while the red ones are priorities, as they indicate safety. The opening of labels can be done by any person, besides putting the label on the physical (equipment) has to realize the opening of it in the SAP System. There is a deadline to solve the labels, blue has a deadline of 15 days and red of seven days depending on the impact that will happen on the line.

These needs are raised at the weekly APTs meeting, by passing them on to the planned status (blue) and prioritized (red) for the following week. In addition to the weekly APT meetings, there are meetings in front of the management boards in view of each line. These meetings discuss the main problems and actions that were carried out or not, an information alignment occurs and the decision making takes place in loco for the next events. These exchanges of information are recorded in the meeting minutes and logbooks of each leader.

Downtime is accounted for by a timer and reported to the system after this number is counted is shared with everyone involved. There is a stratification of that time and a plan of action is done to end idle time. The detail of the downtime is presented in a report called PKEs (Kaizen leaders and development) of each area, where the stratification mentioned above is carried out in a more elaborate way, detailing the entire process of inactivity being reported in meetings for all involved.

## 4.4 Quality

The quality criterion works the quality of the components in a process. Quality must be ensured at all stages in order to ensure good quality products and productivity.

As regards the quality of the raw material delivered by the supplier, the company's policies regarding the quality of the raw materials are followed strictly, in addition to strict procedures that must be complied with in order to avoid failures in the company manufacturing processes. Regarding the separation of the solvent residues in relation to the water flow, in the construction of the unit, all the planning for the waste disposal was carried out. The pipelines are properly identified throughout the production process and are directed to the determined locations. Finally, the disposal is carried out by outsourced companies that meet the environmental policies of the company.

As for the bags, packaging and other hazardous materials and their separation, all materials are allocated in their respective places as defined by the standard required by the industry. Non-hazardous materials are usually stored in the warehouse inside the unit, and hazardous materials are placed in the external areas of the company. For example, the gases are placed in the external areas as they ease the safety risk in the event of an explosion. In terms of calibration of the equipment and meters, some equipment is calibrated in the company's own laboratory, however, there is other equipment that is calibrated externally by outsourced companies, as they require specific parameters and professionals to handle the equipment properly, such as photo-analysis.

In conclusion, for the final test to ensure the quality of the products, there is a quality procedure for this stage in each production line. During the manufacturing processes are performed by the operators themselves and depending on the line is withdrawn a certain amount of packaging to pass through analysis in the quality laboratory and obtain the release of the batch to the distribution centers.

## 5 Discussion

The results indicate that, in relation to the criterion of materials and inventory, the results indicate an efficient management with the use of specific instruments of product monitoring in the question of environmental performance, health, and safety. Inventory management takes place, ensuring the rationalization of processes and the flow of materials. Its execution occurs periodically.

Chemicals are monitored at all stages of the production process, including their disposal. Therefore, in relation to the criterion of materials and inventories, the company adopts lean production practices that help in the management, as well as in the identification of possible wastes of materials.

As for the training criterion, the company has a constant process of investing in the machinery and consequently in the training of the employees. The company's own storage area is defined as the deposit of finished products, evidencing the concern not to form stocks in accordance with lean thinking. In the same way, it was observed that overproduction, movement and production delays occur rarely according to the evidence and indicators presented.

All internal projects involving training use the TPM, in addition to the training and development pillar that adopts practices that promote the training and development of continuous skills in the employees. In summary, employees at the most diverse hierarchical levels are aware of the importance of adopting green lean manufacturing practices, a reflection of the training and development policy implemented.

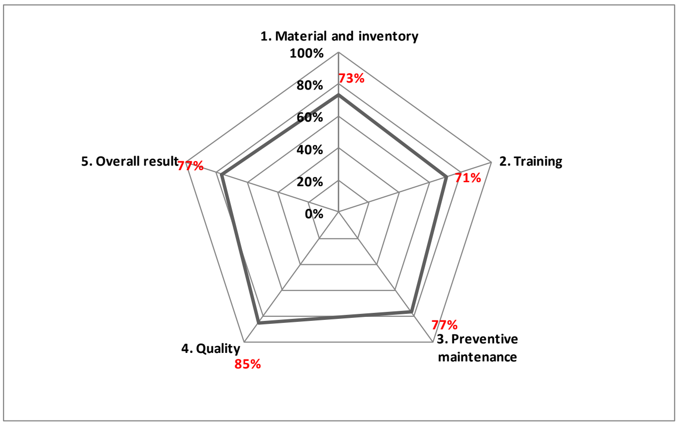
Regarding the preventive maintenance criterion, it was noticed a constant preoccupation with the maintenance of the machines and equipment by means of the total productive maintenance; monitoring of storage tanks; training and collaboration; and adoption of the 5S program. The adoption of visual management allows the definition of parameters and standardization in maintenance. Thus, solid procedures of maintenance and training of employees have been demonstrated in order to guarantee productive efficiency.

In the quality criterion, the raw materials of the suppliers meet the strict quality criterion, as well as rigid procedures to avoid failures in the production process. The factory project addressed environmental issues. Equipment and meters are monitored for calibration in order to guarantee the reliability of the production process, as well as each production line, has a quality procedure to ensure compliance with requirements and increase productivity.

When considering the wastes (leaning, leaning, overproduction, transport, super processing, stock, movement, defects and people), the studied company proved to be well prepared with regard to the adoption of green lean manufacturing practices, since the adoption of management systems disseminated throughout the organization as well as employees trained in the tools so that there are no activities without value added.

The results of the use of Lean 1.0 software in the company presented the following results: the material and inventory criterion obtained 73% of lean practices, the training criterion obtained a result of 71%, preventive maintenance presented a result of 77% and the quality criterion reached result of 85%. Finally, the company achieved an overall average of 77% in the lean manufacturing evaluation focused on the adoption of green practices (Figure 2).

**Figure 2** – Results of evaluation of adoption of Lean Manufacturing Pratices
**Source:** Authors



Regarding the literature review, the operationalization of the research through a case study corroborates the results found in Walter & Tubino (2013) in which they indicated the case study as the methodological approach most used in this area.

The reduction of lead times of processes, costs and quality increase observed in the company meet the concepts of lean thinking pointed out in Shingo, (1996), Womack *et al*. (2004) and Liker (2005). The company adopts SMED practices in agreement with Shingo (2000), besides practices for adoption of the pull production system (HOOP & SPEARMAN, 2004), elimination of Muda (GHINATO, 1995; LIKER, 1996) and continuous flow of products (MONDEN, 1984).

Regarding the synergy between lean and green manufacturing observed in the research, the company adopts several green practices in its production process, reducing the environmental impact according to International Trade Administration (2010) and Bergmiller (2006). It uses resources efficiently, especially water, and in terms of efficient resource improvement, the company manages environmental costs (BLACK & PHILLIPS, 2010); adopts Operational Management System that takes care of the management of chemical products; 5S Program; visual management (OHNO, 1997); environmental and training indicators (PAT and line mapping) similar to that observed in Sobral *et al*. (2013).

The company is in an advanced stage in the application of TPM, in addition to the implementation of Program 5S; Kaizen philosophy; the APTs (autonomous production team); FISPQ (Material Safety Data Sheet); DSS (Sustainable Security Dialogue) and BOS (Safety Occurrence Bulletin) reinforce the mutual benefit of applying such practices (DUES *et al*., 2013), reducing production costs and the environmental impact of the plant (PAMPANELLI *et al*. 2014) considering the Amazonian region.

Therefore, it is observed a company that seeks a synergy between the lean and Green manufacturing practices pointed out in Black & Phillips (2010), Dhingra *et al*. (2014) and Gupta (2016) with manufacturing strategies based on the sustainable manufacture of Jawahir *et al*. (2006).

In conclusion, the approach to evaluating green practices of lean manufacturing allowed the identification of green practices aimed at reducing waste, streamlining processes, improving operational efficiency and increasing productivity as pointed out in Kumar & Thomas, 2002). The results indicated an overall average of 77% relative to the adoption of green practices corroborating the company at an advanced stage of lean thinking. It was observed the possibility of integrating applied theory in a new context, in the case of lean manufacturing in an industry located in the Amazon, besides helping to solve real problems in a richer and better way from the instrument adopted according to Barrat *et al*. (2011) and McCutcheon & Meredith (1993).

## 6 Conclusion

Lean Manufacturing or Lean Manufacturing is much more than a management tool, it is a management philosophy focused on the identification, quantification, and management of processes in order to continuously seek to reduce waste. Considering the results presented and discussed, it is believed that the objective of this article has been reached.

The main results are (1) the reduction of lead time in the processes; (2) the possibility of reducing costs; (3) and increasing quality. Another point of contribution was the reduction of inventories and consequently the gain of physical space that was previously destined to the stock. With the implantation of the Lean culture, it was possible to notice the impacts in the organizational environment, the employees reported that before the implantation there was no internal organization and the processes were not standardized. The results of using the Lean 1.0 software in the company indicated the quality and preventive maintenance criteria with better results and poorer performance materials and inventory.

Among the limitations of the research is the application in only one company and as suggestions for future research indicates the need to apply the methodology in other companies of the same and other sectors with a view to making comparisons between organizations.

Therefore, knowing the lean manufacturing routines focused on the adoption of green practices developed in the company adds value to the knowledge, improvement, productivity, and safety in the processes, besides enabling the identification and resolution of real problems of the company from the integration between the theory and practice. The relevance of the research lies in the application of an approach that makes it possible to analyze the synergy between lean manufacturing and environmental issues in the search for waste reduction, operational efficiency and increased competitiveness.

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